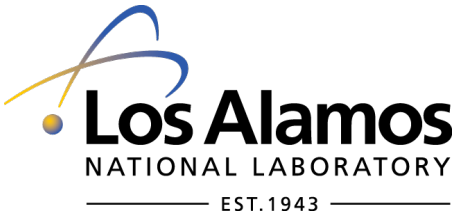
QIS in New Mexico

Ivan H. Deutsch
Center for Advanced Studies
Department of Physics and Astronomy

THE UNIVERSITY of NEW MEXICO

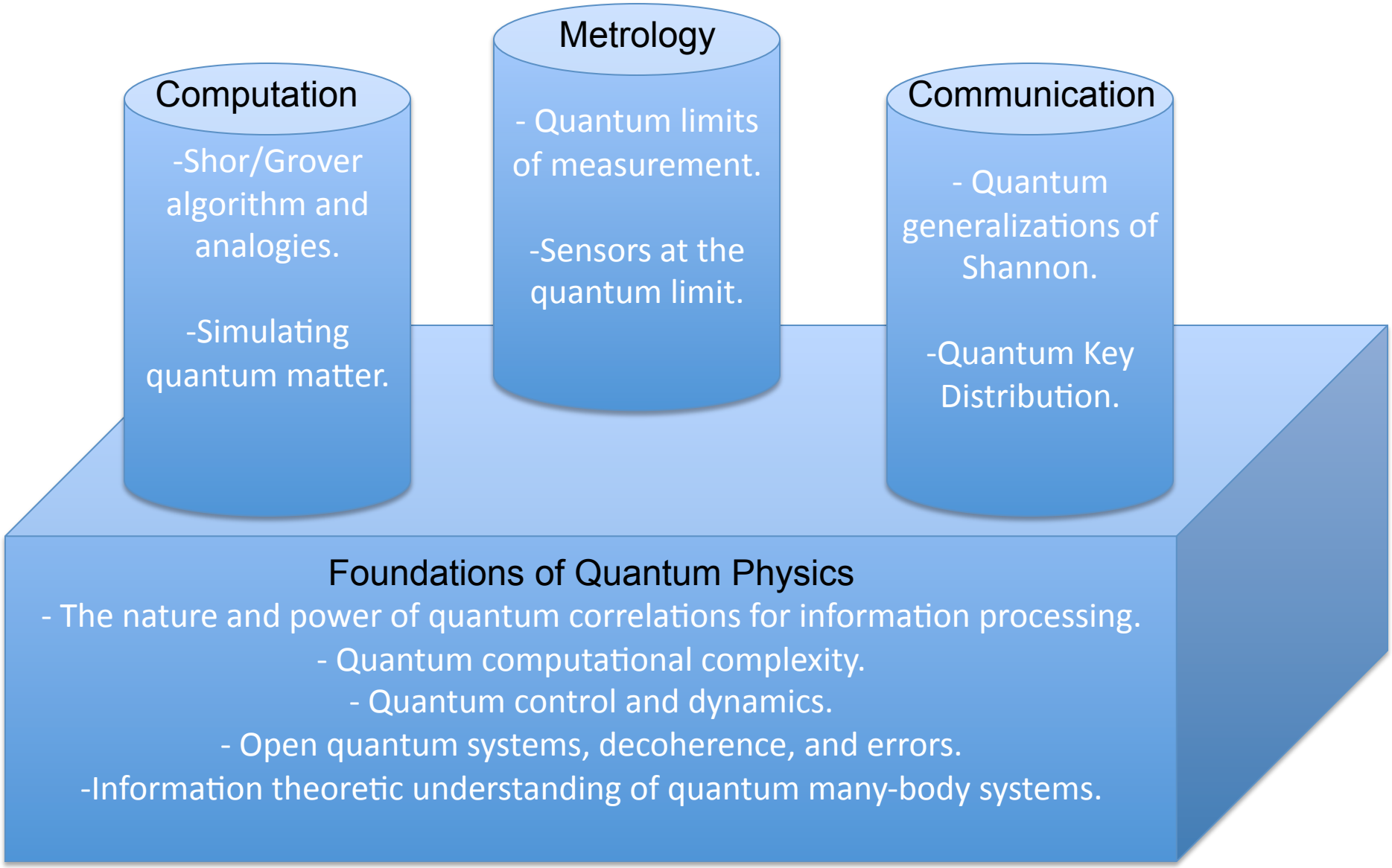
Sandia National Laboratories



Information is Physical
Not "It" but "Bit"

- The ability of a device to process information is constrained by the *laws of physics* that govern the workings of that device.
- Quantum Information Science is the study of quantum physics as a resource for information processing tasks.
- Interdisciplinary at its core and ambitious in its goals, QIS requires new modes of education and research partnerships between universities, national laboratories, and industry.

Pillars of QIS



Key Challenges for QIS

- Preparation and measurement of individual quantum systems.
- Coherent control of individual subsystems and their interactions.
- Robustness to errors.
- Deeper understanding of the power of quantum information processing.
- Applications. *Building a Quantum Computer.*

Science and engineering issues intertwined.

QIS in New Mexico

Sandia National Laboratories

~10 staff, 6 postdocs

- Engineering QI technologies
  - Semiconductor & MEMS device physics, AMO, integration with classical electronics.
- Collaborations across disciplines
  - Device fab, optics, high-performance computing, modeling and theory.

Los Alamos NATIONAL LABORATORY EST. 1943

~40 staff, 15 postdocs

- Quantum Initiative (quantum.lanl.gov)
- Multidisciplinary QI basic research
  - AMO, decoherence, algorithms, communication, materials
- Applied QI technologies
  - Quantum Key Distribution

THE UNIVERSITY of NEW MEXICO

~5 faculty, ~20 students, 1 postdoc

- QI education and research (Physics & CS):
  - Foundations, control, algorithms, metrology, AMO physics
- Center for Advanced Studies
  - Interdisciplinary center for QI: Seminars, visitors, summer schools
- SQuInT: Southwest Quantum Information and Technology:
  - Network of universities, national laboratories, industry. 12 year history.

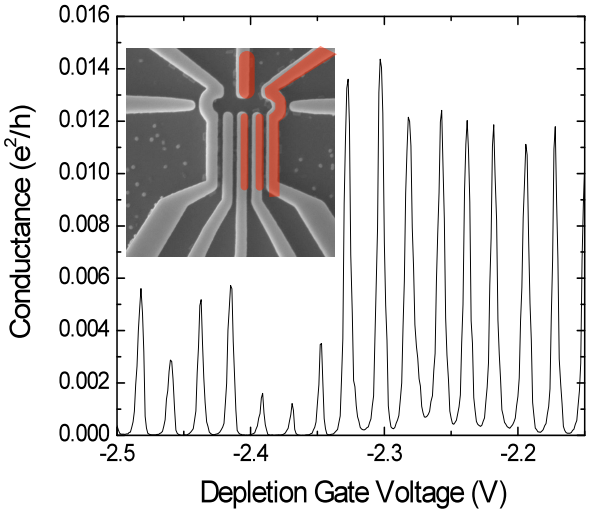
<u>New Mexico QIS Alumni Include:</u>

LANL: Manny Knill, Ray Laflamme, Paul Kwiat

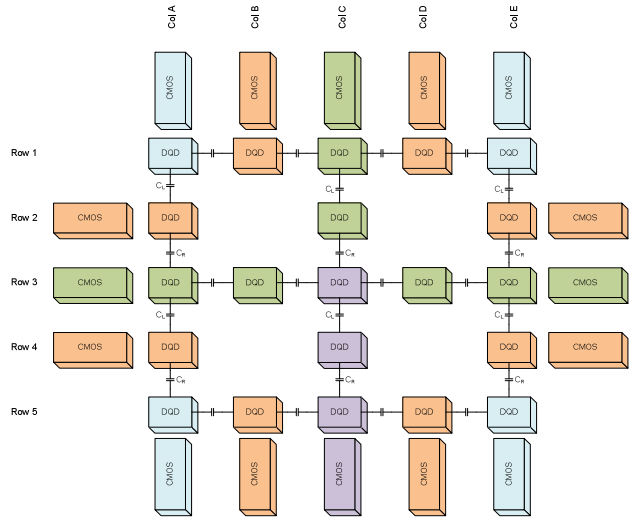
UNM: Mike Nielsen, Chris Fuchs, Gavin Brennen

SFI: Seth Lloyd, Dave Bacon

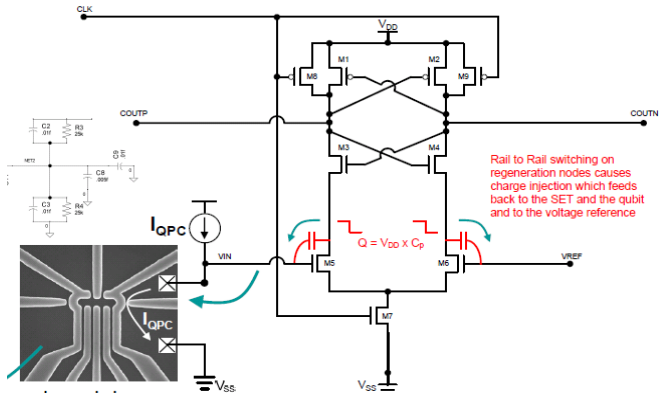
Quantum Information Science and Technology (QIST)



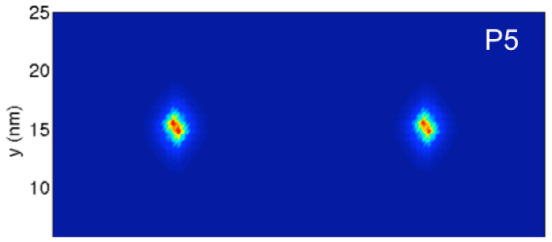
Physical Qubit: Silicon Double Dot



Realistic Design for Logical Qubit



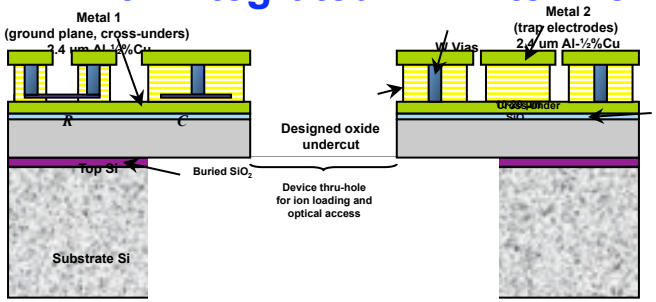
Integrated Electronics



Qubit Modeling

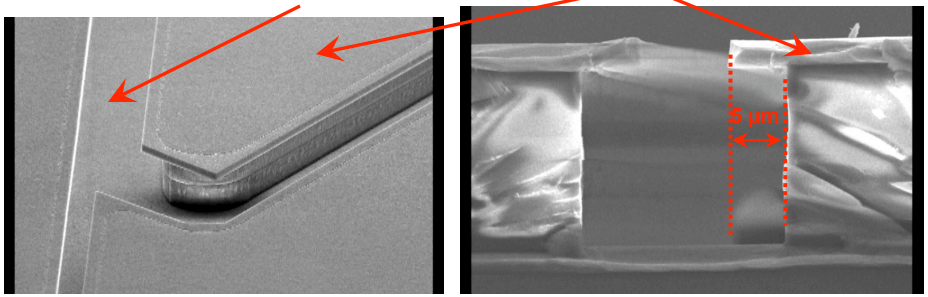
Sandia Trap and Micro Optics Engineering and Trap Diagnostics

Surface + Thru-hole Ion Trap Chips with Integrated RF Filter Components



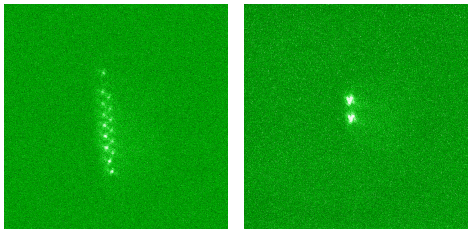
Schematic of Sandia ion trap chip with vias, electrode cross-overs, and capacitors and resistors for RF filtering.

Al trap ground plane and electrodes

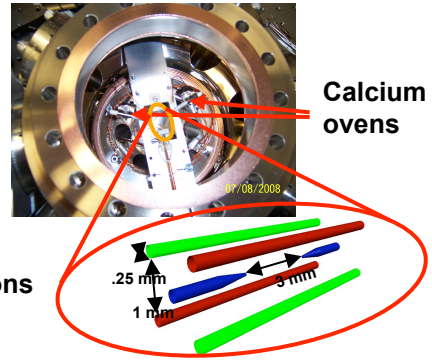


These SEM images show the controlled undercut of surface trap electrodes. The dielectric between trap electrode and ground is set back by 5 μm from the edge of the electrode.

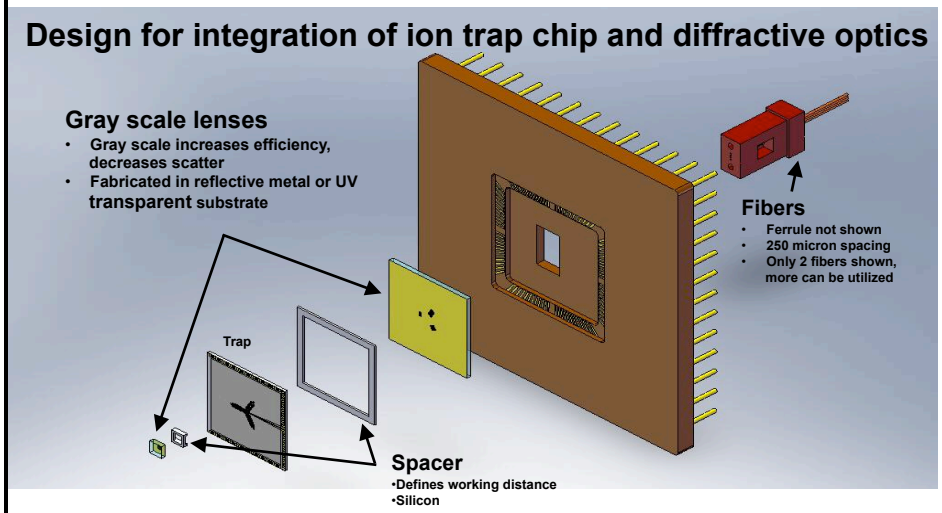
Sandia Ion Trap Diagnostics

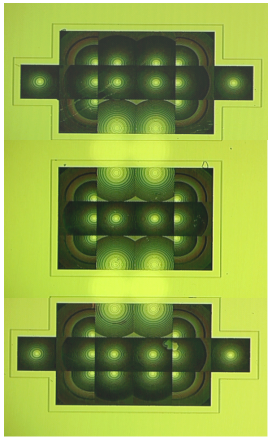


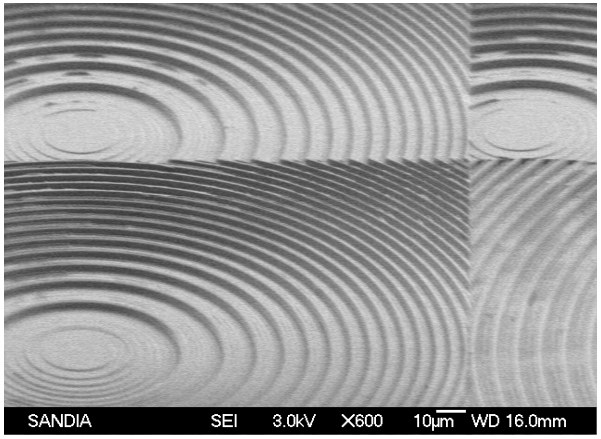
Images of crystals of trapped calcium ions



Integration of Diffractive and Micro Optics with Ion Trap Chips





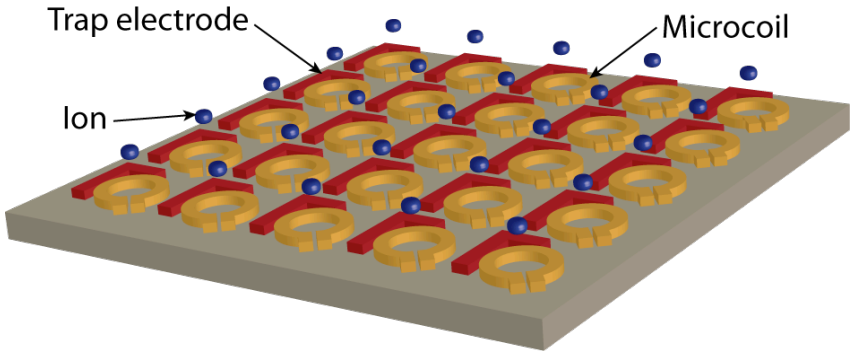


(L) Optical microscope bird's-eye view of a Sandia DOE array for cascaded optical computing. (R) SEM of the 100% fill-factor optical interconnect array in fused silica (R) fabricated at Sandia.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Technologies for Manipulating Ions and Atoms

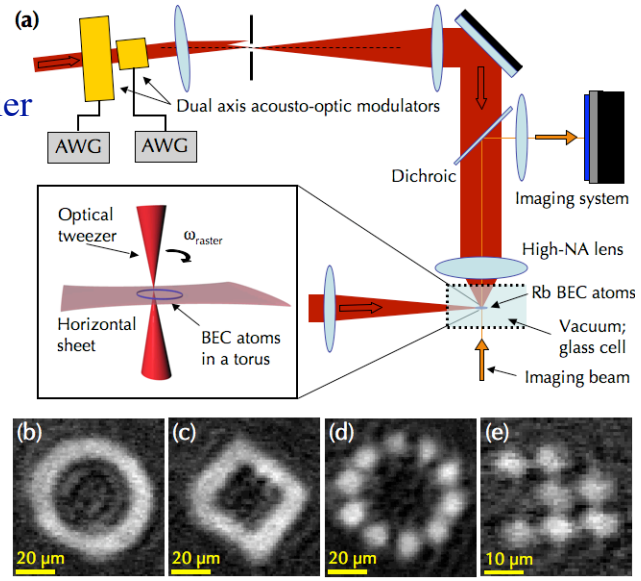
Chiaverini



RF Microtraps

Investigating applications to:
- Quantum simulation
- Quantum computing

Boshier

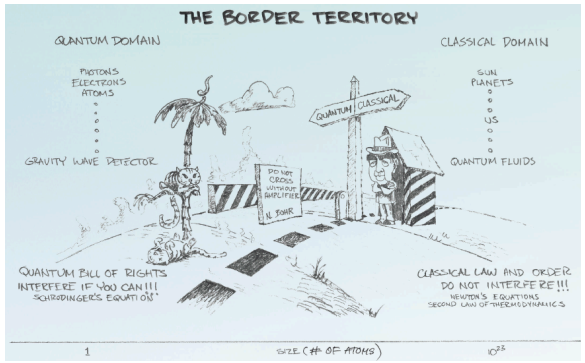


BECs in Time-Averaged Optical Dipole Potentials

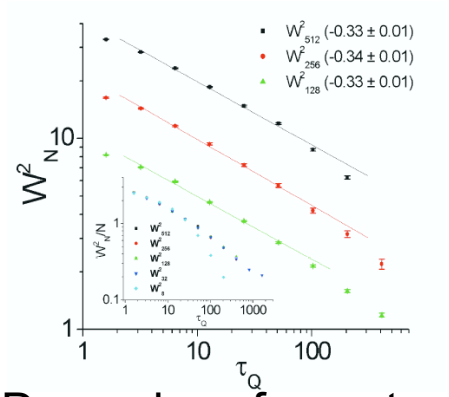
Investigating applications to:
- Interferometry
- Quantum phase transitions

QIS Theory @ LANL

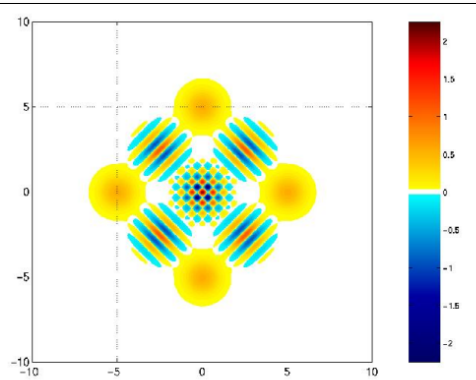
Zurek



Decoherence and quantum to classical transition

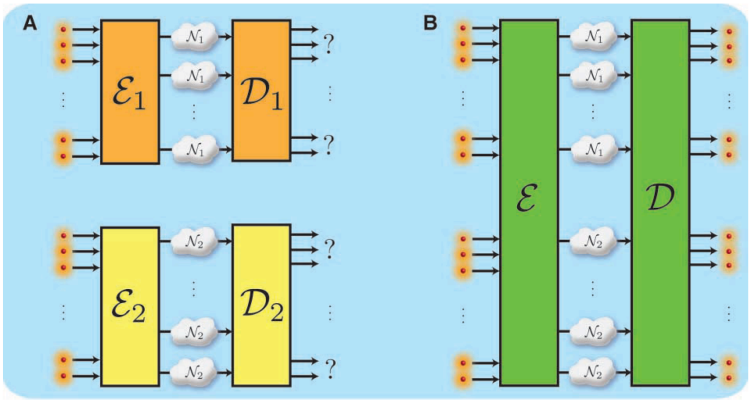


Dynamics of quantum phase transitions



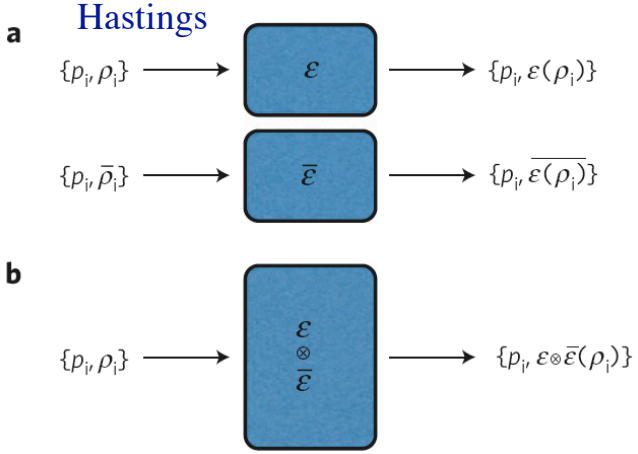
sub-Planck Structure:
Quantum state preparation for metrology

Yard



Quantum capacity is not additive.

Hastings



Classical capacity is not additive.

Quantum Key Distribution at LANL

distribution of secret cryptographic keys by quantum communications

Free-space QKD > 1994

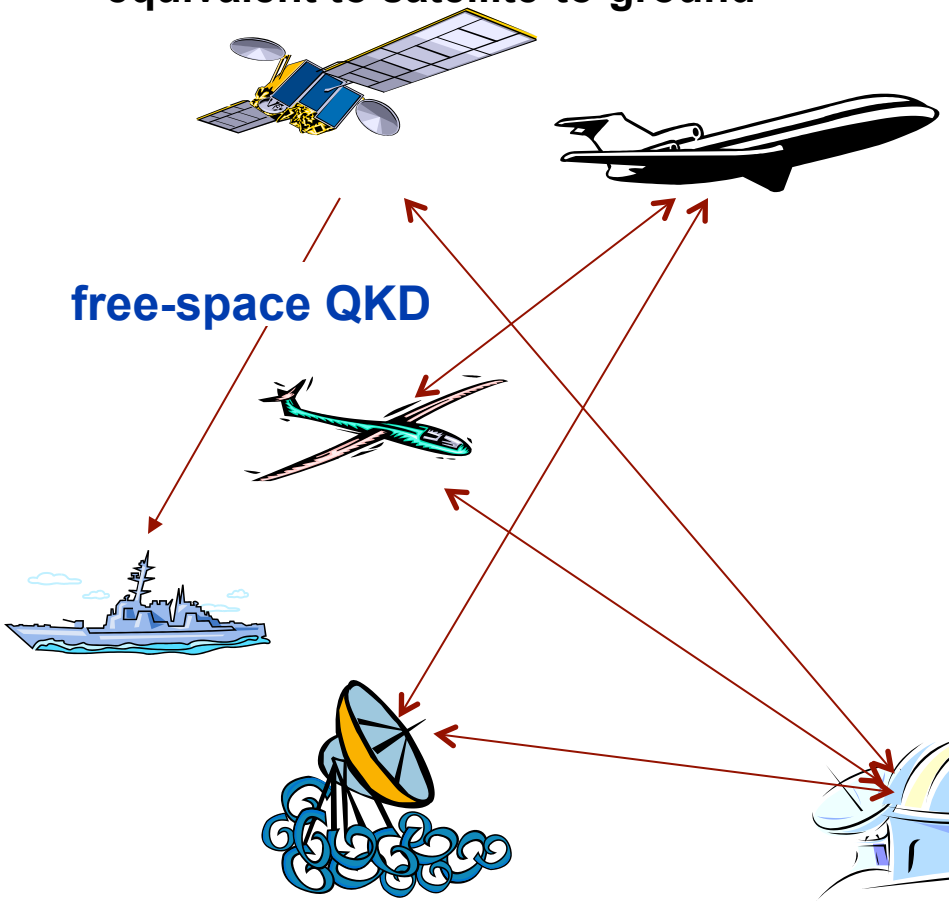
- **LANL invention: a methodology that makes free-space & satellite quantum communications possible**
- **demonstrated in daylight over outdoor ranges optically equivalent to satellite-to-ground**

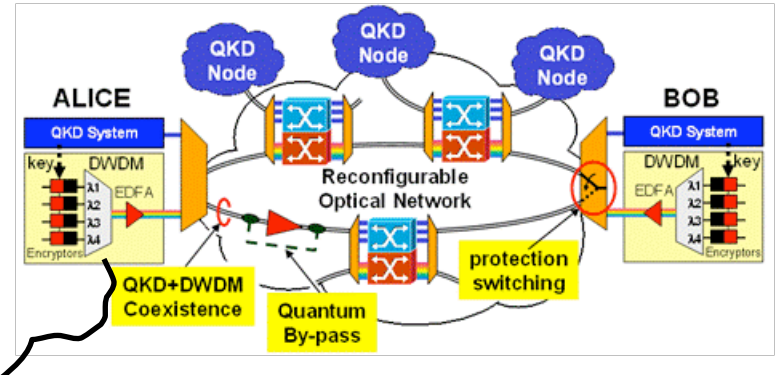
Hughes

United States Patent [19]

Hughes et al.

[54] SECURE COMMUNICATIONS WITH LOW-ORBIT SPACECRAFT USING QUANTUM CRYPTOGRAPHY





Optical fiber QKD > 1993

- **QKD demonstrated in active transparent enterprise & metro-area networks**
- **record > 140km range demonstrated with ultra-strong security**

global secure communications using satellite QKD

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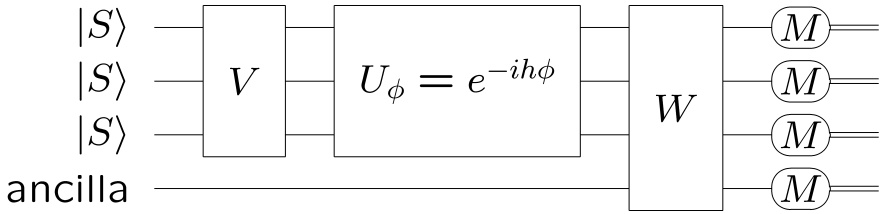
Los Alamos NATIONAL LABORATORY

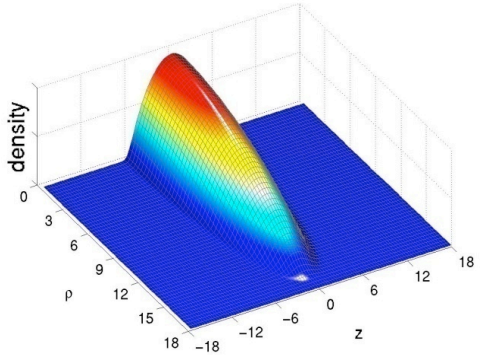
Information Physics Group UNM (and UofA)

Caves



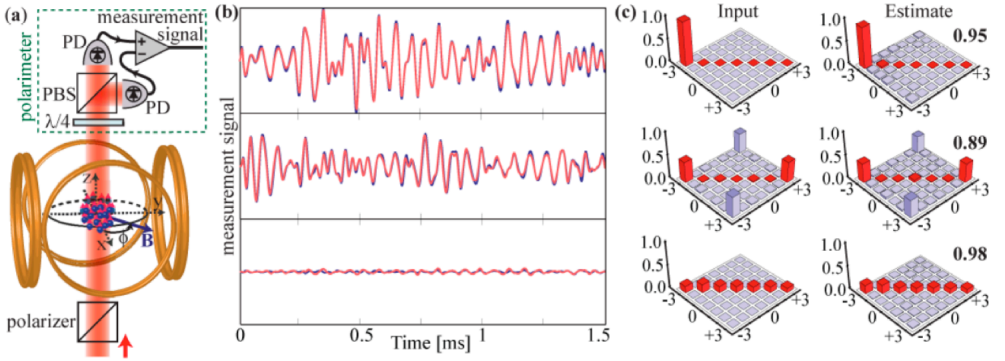
sub-Heisenberg-limited metrology:

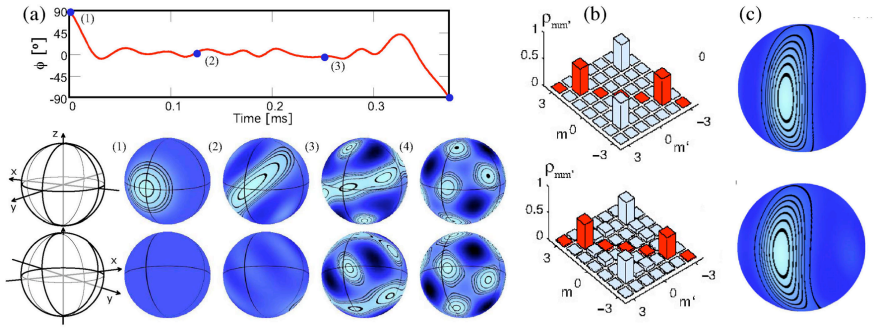
Information theoretic limits to precision measurement.



Implementation in nonlinear quantum system (e.g. BEC nonlinear Ramsey interferometry)

Deutsch & Jessen



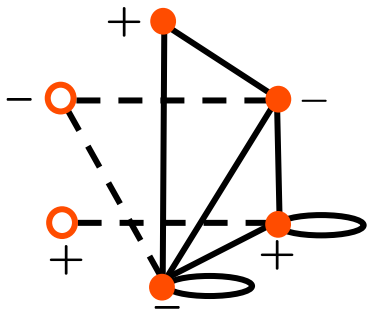


Quantum control and measurement:

Interface between abstract theory and laboratory implementations of quantum state preparation, quantum logic, and quantum state reconstruction.

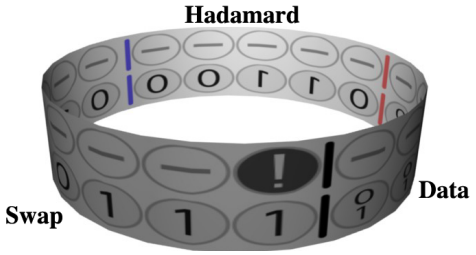
Information Physics Group UNM

Caves



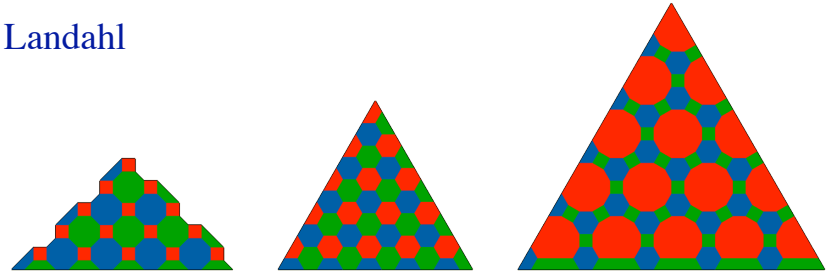
Generalized graph state:
Quantum vs. classical correlations and the power of quantum computation.

Landahl



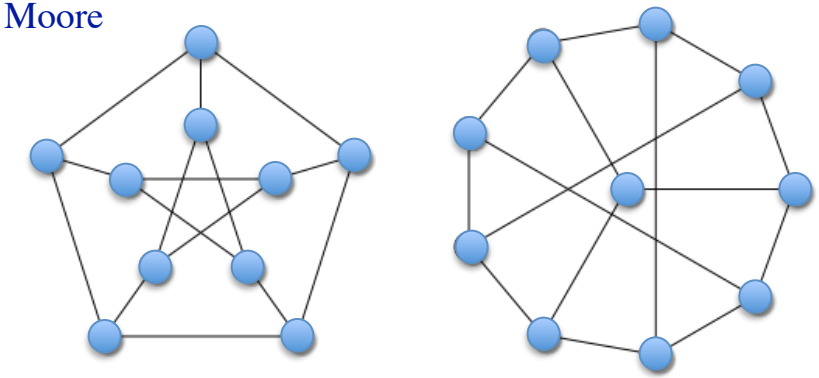
Continuous-time quantum computation :
Universal quantum walk on a 1D ring.

Landahl



Color codes for quantum error correction :
High threshold with low overhead.

Moore



Graph Isomorphism:
Hidden symmetries not efficiently found by a quantum computer can lead to unbreakable classical cryptosystems.

Southwest Quantum Information and Technology

Eleventh Annual Meeting, February 19-22, 2009
Seattle, Washington

- Meeting Home
- Contribute
- Register (Closed)
- SQuInT Program
- IAS Program
- Participants
- Travel
- Lab Tour

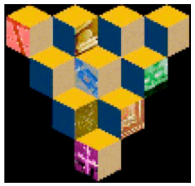
11th Anniversary SQuInT Annual Workshop

Seattle, Washington, February 19-22, 2009

The 11th Annual SQuInT Workshop will be hosted by the University of Washington, locally organized by Boris Blinov and Dave Bacon, and SQuInT Coordinator Ivan Deutsch.

Invited Speakers:

- Andrew Childs (Waterloo)
- Luming Duan (Michigan)
- Jack Harris (Yale)
- Chris Monroe (Maryland)
- Barbara Terhal (IBM)
- David Weiss (Penn. State)



Satellite Meeting: Workshop on Integrated Atomic Systems II

Seattle, Washington, February 18-19, 2009

Workshop begins the afternoon of February 18!

In association with SQuInT, the Workshop on Integrated Atomic Systems II will bring experts from the areas of atomic physics (trapped neutrals and ions), MEMS technology, packaging and microsystems integration to explore opportunities for creating highly functional systems based on the advances in atomic physics. Prelimary Program and Invited Speaker List. This is the second meeting, following on the success of the inaugural meeting in November 2007.

Integrated Atomic Systems Organizers: Dana Anderson, Matthew Blain, Boris Blinov, Jungsang Kim, Peter Schwindt, and Dick Slusher

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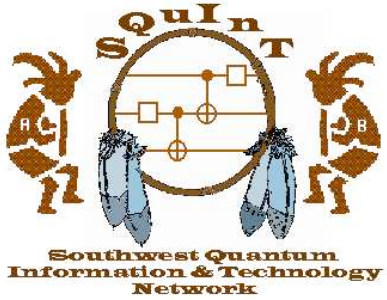
Southwest Quantum Information & Technology (SQuInT)



UNIVERSITY OF CALGARY

Jet Propulsion Laboratory

SQuInT serves QIS Community
- Interdisciplinary.
- Theory meets experiment.
- Student centered.

Topical Group on Quantum Information

Governance
Newsletters
Meetings
APS Fellowship
Prizes & Awards
Careers
Image Gallery
About GQI
Resources

Topical Group on Quantum Information

The mission of the Topical Group on Quantum Information is to promote the advancement and diffusion of knowledge concerning the physics of quantum information, computing, fundamental concepts, and foundations. The Topical Group will serve as a focus for theoretical and experimental research in these and related areas. Research topics of direct interest include quantum entanglement, quantum communication, quantum cryptography, quantum algorithms and simulations, physical implementations of qubits, quantum error correction, fault-tolerant quantum computation, quantum measurements, open quantum systems, quantum coherence, control of quantum dynamics, the quantum-classical correspondence, and the conceptual and mathematical foundations of quantum theory.

▸ Full Mission Statement

Unit Contact

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Professor, Regents Lecturer
Director, Center for Advanced Studies
University of New Mexico, Department of Physics and Astronomy
Email | Homepage
Phone: (505) 277-1502 FAX: (505) 277-1520

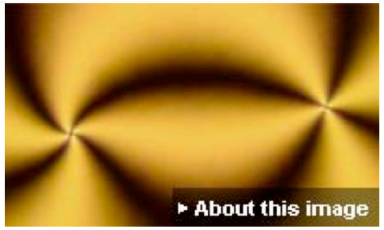
Upcoming Meetings

APS April Meeting 2009
May 2-5, 2009

APS April/AAPT Meeting 2010
February 13-16, 2010

APS March Meeting 2010
March 15-19, 2010

▸ View APS Meeting Calendar



Quick Links

▸ Executive Committee

APS Members
- Join This Unit
- Member Directory

Join APS

About APS

LANL is the home of the QIS Research Roadmap: http//qist.lanl.gov

Technology Experts Panel (TEP) Membership:

Chair: Dr. Richard Hughes – Los Alamos National Laboratory
Deputy Chair: Dr. Gary Doolen – Los Alamos National Laboratory
Prof. David Awschalom – University of California: Santa Barbara
Prof. Carlton Caves – University of New Mexico
Prof. Michael Chapman – Georgia Tech
Prof. Robert Clark – University of New South Wales
Prof. David Cory – Massachusetts Institute of Technology
Dr. David DiVincenzo – IBM: Thomas J. Watson Research Center
Prof. Artur Ekert – Cambridge University
Prof. P. Chris Hammel – Ohio State University
Prof. Paul Kwiat – University of Illinois: Urbana-Champaign
Prof. Seth Lloyd – Massachusetts Institute of Technology
Prof. Gerard Milburn – University of Queensland
Prof. Terry Orlando – Massachusetts Institute of Technology
Prof. Duncan Steel – University of Michigan
Prof. Umesh Vazirani – University of California: Berkeley
Prof. K. Birgitta Whaley – University of California: Berkeley
Dr. David Wineland – National Institute of Standards and Technology: Boulder

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LANL is the home of the QIS Research Roadmap: http//qist.lanl.gov

- **where would we like QIS to be in the future?**

- **what will it take to get there ?**

a Research Roadmap:

apply some gentle direction

describe state-of-play and likely progress

identify opportunities and gaps

an aid to the research community and a descriptive tool for program management

- **ver 2.0 quantum computation roadmap**
  - released April 2004
- **ver 1.0 quantum cryptography roadmap**
  - released June 2004: QKD focus
  - funded by ARDA 2002 - 2005

LA-UR-02-6900

A Quantum Information Science and Technology Roadmap

Part 1: Quantum Computation

Report of the Quantum Information Science and Technology Experts Panel

"… it seems that the laws of physics present no barrier to reducing the size of computers until bits are the size of atoms, and quantum behavior holds sway."

Richard P. Feynman (1985)

Disclaimer:
The opinions expressed in this document are those of the Technology Experts Panel members and are subject to change. They should not to be taken to indicate in any way an official position of U.S. Government sponsors of this research.

December 1, 2002

Version 1.0

ARDA

This document is available electronically at: http://qist.lanl.gov

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